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Chapter Seventeen
DRAINAGE AND IRRIGATION DESIGN

Chapter Seventeen presents policies and criteria for the design of facilities to accommodate surface water. Included are policies and criteria for the design of:

1. pipe culverts,
2. special drainage facilities,
3. irrigation facilities,
4. storm drains, and
5. underdrains.

The chapter also presents design policies for special-purpose large culverts, guidelines for measuring culvert or trench excavation, and a group of general reference tables. See the *AASHTO Model Drainage Manual* for additional information on highway drainage. The Hydraulics Section has revised and adopted Chapters Seven, Nine, Ten and Thirteen of the *AASHTO Model Drainage Manual*. These chapters are available on MDT's website.

17.1 PIPE CULVERTS

Nearly all drainage and irrigation facilities involve the use of some type of pipe culvert. Pipe culvert design requires a determination of:

1. pipe material,
2. design service life,
3. pipe size,
4. structural requirements,
5. multiple pipe installation requirements,
6. culvert end treatments,
7. culvert inlet and outlet edge protection,
8. culvert lengths,
9. culvert bedding/foundation, and
10. culvert excavation and backfill.

17.1.1 Pipe Material

Pipes may be fabricated from concrete, steel, aluminum or plastic material. Material selection will be based on an evaluation of the project location's soils and water conditions. Provisions will be included to permit optional bids for pipes of different

materials. The Hydraulics Section will provide information for the different pipe materials including wall thickness, size of corrugations and class of concrete for all culverts larger than 600 mm in diameter. The designer will be advised in writing of these decisions. For additional information, see the Department's policy for Optional Material for Culverts.

For reconstruction projects where existing pipes can be used in place and require lengthening, the additional lengths of pipe usually will be the same material as the existing pipe. These special conditions will be identified in recommendations at the time of the field survey.

17.1.2 Design Service Life

Address the issue of culvert service life during the preliminary field review. The Hydraulics Section will use service life to determine the required wall thickness, type of coating and any special requirements for new pipes. The Hydraulics Section will evaluate the corrosive soil report to predict design service life. For specific design criteria, see the "Culvert Service Life Guidelines" as published in the *Hydraulics Manual*. The remaining service life of existing pipes will guide the decision to replace the pipes or use them in place. The culvert service life will comply with the following guidelines:

1. The design service life for new or replacement culverts will be:

    a. 40 years for approach pipes*;

    b. 75 years for mainline pipes;

    c. 75 years for storm drains; and

    d. for irrigation pipe, siphons and active streamflow pipes, the life of the pipe is the time it takes for the first perforation to occur. Therefore, the average life pulled from the AISI charts must be doubled (e.g., for design purposes a mainline irrigation crossing effectively needs a 150-year life and a minor irrigation approach pipe needs an effective 80-year life).

    * Approach pipes will not receive bituminous coating unless specifically recommended.

2. The design service life for overlay and minor widening projects will be 20 years for all in-place culverts.

3. The design service life for pipes used in place on reconstruction and major widening projects will be:

a. 25 years for all in-place pipes except as follows;
b. 50 years for all pipes where any one of the following applies:

- fill heights are over 4.5 m;
- ADT is greater than 5,000;
- grade raises over 1.5 m;
- all 4-lane highways; and/or
- extensions greater than 50% of the in-place length of the culvert.

17.1.3 Pipe Size

The locations and sizes of existing pipe culverts will be documented at the time of the location or pick-up survey. The dimensions of existing pipe sizes will be converted to the metric system and expressed to the nearest millimeter to reflect the true size of the pipe (e.g., 36” CSP = 914.4 mm, round to 914 mm). Any problems with existing culvert facilities, such as insufficient capacity, roadway overtopping, erosion, pipe damage or debris/ice obstruction, should also be noted at the time of survey. Where new alignment is proposed, the location of new pipe culverts should be recommended by field personnel.

All new mainline drainage culverts must be at least 600 mm in diameter. All new irrigation pipe culverts and approach culverts must be at least 450 mm in diameter. Equivalent arch pipe may be used.

The Hydraulics Section will provide recommendations for all irrigation crossings greater than 450 mm in diameter and drainage crossings requiring pipes greater than 600 mm in diameter. The road designer will determine the location of all minimum size drainage crossings and will design all inlet and outlet ditches and roadside ditches for positive drainage.

17.1.4 Structural Requirements for Reinforced Concrete Pipe

Reinforced Concrete Pipes (RCP) are identified by "class" numbers, depending on their respective strength characteristics. Four classes are available — Classes 2, 3, 4 and 5. The higher the number, the stronger the pipe. Figure 17.1A identifies permissible fill heights for various classes of pipe and bedding. Concrete Arch Pipe will normally be Class 3, Wall "B". Figure 17.1B provides the equivalent RCP diameters for reinforced concrete pipe arches.

CLASS OF PIPE	MAXIMUM FILL HEIGHTS (m) ⑤				
	CLASS C BEDDING③		CLASS B BEDDING④		CLASS B_1 BEDDING (IMPERFECT TRENCH)①
	P=0.0②	P=0.9	P=0.0②	P=0.7	
2	3.7	2.7	4.3	3.4	10.7
3	4.9	4.0	6.1	4.3	15.2
4	7.0	5.2	8.5	6.7	22.9
5	10.7	8.2	12.8	9.8	30.5
4000D②	-	-	-	12.2	-

P = Projection Ratio. A projection ratio of 0.0 is a trench condition and may be achieved by excavation below existing ground or by building embankment and excavating the trench. Projection ratios of 0.7 and 0.9 are for embankment conditions.

Notes:

① *Imperfect trench method will be used only when specified by the Hydraulics Section.*

② *Not to be used without Hydraulic Section's approval. For more information on bedding, see the* MDT Detailed Drawings.

③ *Use Class C bedding and the P = 0.9 column for pipes ≤ 1200 mm, to determine the required class of pipe for a specific fill height.*

④ *Use Class B bedding and the P = 0.7 column for pipes > 1200 mm, to determine the required class of pipe for a specific fill height.*

⑤ *This fill height table was developed using the indirect design method detailed in the ACPA* Concrete Pipe Design Manual. *This table applies only to pipes having "B" wall thickness.*

STRUCTURAL REQUIREMENTS FOR RCP

Figure 17.1A

SPAN (mm)	RISE (mm)	EQUIVALENT DIAMETER (mm)
460	280	375
560	345	450
660	395	525
725	460	600
920	570	750
1110	675	900
1300	795	1050
1485	915	1200
1650	1015	1350
1855	1145	1500
2235	1370	1800
2590	1575	2100

Table values are from AASHTO Materials, Standard Specifications for Transportation Materials, Part 1, M206M.

Note: RCP arches are identified by the metric sizes shown above. Until the industry converts to metric, there will be no physical product change. Current accepted tolerances allow English sizes to meet metric size requirements.

REINFORCED CONCRETE PIPE ARCHES

Figure 17.1B

Pipes should not extend into the surfacing section. Although not desirable, pipes may extend into the special borrow course. Consult the Hydraulics Section for minimum cover requirements for concrete pipe if cover is less than 0.5 m.

17.1.5 Structural Requirements for Corrugated Steel Pipe

Metal thickness and soil support are the principal measures of strength in Corrugated Steel Pipe (CSP). The required metal thickness depends on the following factors:

1. height of fill over pipe,
2. dimensions of corrugations,
3. shape of pipe,
4. soil compaction,
5. corner bearing pressure, and
6. soil corrosiveness.

Figure 17.1C illustrates some of the relationships between these factors. The figure shows the minimum and the maximum permissible fill heights for each combination of pipe size and metal thickness. Maximum fill height is measured from the top of the pipe to the point of maximum cover. The depth of surfacing (e.g., bituminous, gravel, concrete) is included in the height of cover. Pipes should be placed at a minimum of 0.1 m to 0.3 m below the bottom of the surfacing section exclusive of special borrow (i.e., surfacing subgrade). Although not desirable, pipes may extend into the special borrow course. See the fill height tables for additional information.

Normally, for steel culvert installations up to 3000 mm in diameter, CSP will be specified for installation. The fill heights for these culverts must fall within the limits of the fill height tables.

The following corrugation sizes will be specified for steel pipe:

1. 68 mm x 13 mm,
2. 75 mm x 25 mm, or
3. 125 mm x 25 mm.

Note the corrugation sizes on the pipe summary.

Most culvert installations will be "round" pipe. Specify pipe arches only where cover is limited or where local conditions make the shape of the pipe arch more effective for carrying the water. Figure 17.1D presents structural requirements for Corrugated Steel Pipe Arch (CSPA) culverts.

68 mm x 13 mm CORRUGATIONS ①, ② WELDED OR LOCK-SEAM STEEL PIPE						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
300	0.5	66.0	82.5			
450	0.5	44.0	55.0			
600	0.5	33.0	41.2	57.8		
750	0.5	26.4	33.0	46.2		
900	0.5	22.0	27.5	38.5	49.5	
1050	0.5	18.9	23.6	33.0	42.5	51.9
1200	0.5	16.5	20.6	28.9	37.2	45.4
1350	0.5		18.3	25.7	33.0	40.4
1500	0.5			23.1	29.7	36.4
1650	0.5			21.0	27.0	33.0
1800	0.5				24.8	30.3
1950	0.5					28.0
2100	0.5					26.0

75 mm x 25 mm CORRUGATIONS ①, ② *WELDED OR LOCK-SEAM STEEL PIPE*						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
1350	0.5	16.9	21.1	29.5	38.0	46.5
1500	0.5	15.2	19.0	26.6	34.2	41.9
1650	0.5	13.8	17.2	24.2	31.1	38.1
1800	0.5	12.6	15.8	22.2	28.5	34.9
1950	0.5	11.7	14.6	20.5	26.3	32.2
2100	0.5		13.5	19.0	24.4	29.9
2250	0.5		12.6	17.7	22.8	27.9
2400	0.5			16.6	21.4	26.2
2550	0.5			15.6	20.1	24.6
2700	0.5			14.8	19.0	23.3
2850	0.5				18.0	22.0
3000	0.5				17.1	20.9

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

In addition, for all pipes less than 2100 mm, the top of the pipe should be located 0.1 m below the bottom of the surfacing subgrade. For all pipes 2100 mm and larger, the top of the pipe should be located 0.3 m below the surfacing subgrade.

Notes:

① *Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.*

② *For a given fill height, the wall thicknesses for both the 68 mm x 13 mm and the 75 mm x 25 mm corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.*

STRUCTURAL REQUIREMENTS FOR CSP (Welded or Lock-Seam)

Figure 17.1C

125 mm x 25 mm CORRUGATIONS ① *WELDED OR LOCK-SEAM STEEL PIPE*						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
1350	0.5	15.0	18.8	26.3	33.9	41.4
1500	0.5	13.5	16.9	23.7	30.5	37.3
1650	0.5	12.3	15.4	21.5	27.7	33.9
1800	0.5	11.3	14.1	19.7	25.4	31.0
1950	0.5	10.4	13.0	18.2	23.4	28.7
2100	0.5		12.1	16.9	21.8	26.6
2250	0.5		11.3	15.8	20.3	24.8
2400	0.5			14.8	19.0	23.3
2550	0.5			13.9	17.9	21.9
2700	0.5			13.2	16.9	20.7
2850	0.5				16.0	19.6
3000	0.5				15.2	18.6

***** *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

In addition, for all pipes less than 2100 mm, the top of the pipe should be located 0.1 m below the bottom of the surfacing subgrade. For all pipes 2100 mm and larger, the top of the pipe should be located 0.3 m below the surfacing subgrade.

Notes:

① *Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.*

STRUCTURAL REQUIREMENTS FOR CSP
(Welded or Lock-Seam)

Figure 17.1C
(Continued)

68 mm x 13 mm CORRUGATIONS STEEL PIPE ARCH (ALL SEAM FABRICATIONS)						
PIPE DIMENSIONS SPAN x RISE (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)① MINIMUM METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
530 x 380	0.6	2.9				
710 x 510	0.6	3.2**				
885 x 610	0.7	2.1**			②	
1060 x 740	0.8	2.1**				
1240 x 840	0.9		2.0**			
1440 x 970③	0.6			2.6**		
1620 x 1100③	0.6			2.8**		
1800 x 1200③	0.6				3.0**	
1950 x 1320③	0.6					3.1**
2100 x 1450③	0.6					3.3**

75 mm x 25 mm OR 125 mm x 25 mm CORRUGATIONS STEEL PIPE ARCH (ALL SEAM FABRICATIONS)						
PIPE DIMENSIONS+ SPAN x RISE (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) ① MINIMUM METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
1340 x 1050	0.6		2.7④			
1520 x 1170	0.6		2.7④			
1670 x 1300	0.6		2.7④			
1850 x 1400	0.6		3.3④		②	
2050 x 1500	0.6		3.5④			
2200 x 1620	0.6		3.2④			
2400 x 1720	0.6		3.4④			
2600 x 1820	0.6			3.1		
2840 x 1920	0.6			3.2		
2970 x 2020	0.6			3.1		
3240 x 2120	0.6				2.8	

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

In addition, for all pipe arches less than 2400 mm x 1720 mm, the top of the pipe should be located 0.1 m below the surfacing subgrade. For all pipe arches 2400 mm x 1720 mm and larger, the top of the pipe should be located 0.3 m below the surfacing subgrade.

** *Based upon a 287 kPa corner bearing pressure. Special foundation investigation required.*

\+ *Nominal dimensions per manufacturer/supplier's product information.*

Notes:

① *Based upon a 192 kPa corner bearing pressure except as noted. Special foundation investigation required when higher corner bearing pressures need to be developed.*

② *Thicknesses above heavy line will not be used unless specified by the Hydraulics Section.*

③ *These sizes should not be used unless site conditions preclude the use of arches with 75 mm x 25 mm corrugations.*

④ *Specify 2.77 mm thickness for 125 mm x 25 mm corrugations.*

STRUCTURAL REQUIREMENTS FOR CSPA
Figure 17.1D

17.1.6 Structural Requirements for Structural Steel Plate Culverts

Normally, for culvert installations larger than 3000 mm, Structural Steel Plate Pipe (SSPP) culverts will be specified. Figure 17.1E provides SSPP criteria for minimum and maximum fill heights permitted with various combinations of pipe size and metal thickness. The Hydraulics Section must specify adequate metal thickness for each installation. The dimension of SSPP will be called out in meters to three decimal places.

Figure 17.1F presents the structural requirements for Structural Steel Plate Pipe Arch (SSPPA) culverts.

17.1.7 Structural Requirements for Corrugated Aluminum Pipe

When Corrugated Aluminum Pipe (CAP) is specified or permitted as an option, determine the metal thickness requirements from Figure 17.1G for the particular conditions of pipe shape and height of fill.

17.1.8 Multiple Pipe Installations

To provide an adequate waterway, it may be necessary to install two or more adjacent culverts at one location. Identify these installations as a "double" or a "triple" installation at the station representing the center of the installation.

The spacing between outside faces of adjacent pipes normally will be a minimum of 1.2 m and a maximum of 1.8 m. If flared end terminal sections are used, specify at least 0.6 m between the outside ends of adjacent terminal sections.

17.1.9 Culvert End Treatments

Consideration should be given to special treatments required for the ends of culvert installations. Specific detailed drawings and criteria for their application are presented below.

The end treatments discussed in Section 17.1.9 apply to both single and multiple-pipe installations. See the *MDT Detailed Drawings* for the standard end treatments.

152 mm x 51 mm CORRUGATIONS STRUCTURAL STEEL PLATE PIPE								
PIPE DIAMETER** (m)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) ①						
		METAL THICKNESS (mm)						
		2.82	3.56	4.32	4.79	5.54	6.32	7.11
1.500	0.5	14.6	21.0	27.5	31.5	38.0	44.7	48.8
1.810	0.5	12.1	17.5	22.9	26.3	31.6	37.3	40.7
2.120	0.5	10.4	15.0	19.6	22.5	27.1	32.0	34.9
2.430	0.5	9.1	13.1	17.2	19.7	23.7	28.0	30.5
2.740	0.5	8.1	11.7	15.3	17.5	21.1	24.9	27.1
3.050	0.5	7.3	10.5	13.7	15.8	19.0	22.4	24.4
3.360	0.5	6.6	9.6	12.5	14.3	17.3	20.3	22.2
3.670	0.5	6.1	8.8	11.4	13.1	15.8	18.6	20.3
3.980	0.5	5.6	8.1	10.6	12.1	14.6	17.2	18.8
4.290	0.6	5.2	7.5	9.8	11.3	13.6	16.0	17.4
4.600	0.6	4.9	7.0	9.2	10.5	12.7	14.9	16.3
4.910	0.7		6.6	8.6	9.8	11.9	14.0	15.3
5.220	0.7		6.2	8.1	9.3	11.2	13.2	14.4
5.530	0.7			7.6	8.8	10.5	12.4	13.6
5.840	0.8			7.2	8.3	10.0	11.8	12.8
6.150	0.8				7.9	9.5	11.2	12.2
6.460	0.8					9.0	10.7	11.6

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

In addition, for all pipes less than 2.120 m, the top of the pipe should be located 0.1 m below the surfacing subgrade. For all pipes 2.120 m and larger, the top of the pipe should be located 0.3 m below the surfacing subgrade.

** *Nominal diameters per manufacturers'/suppliers' product information.*

Notes:

① *Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.*

STRUCTURAL REQUIREMENTS FOR SSPP

Figure 17.1E

SSPPA, 152 mm x 51 mm CORRUGATIONS 457-mm CORNER RADIUS①						
PIPE DIMENSIONS ② SPAN x RISE (m)	MINIMUM FILL HEIGHT* (,m)	MAXIMUM FILL HEIGHT (m) ③				
		MINIMUM METAL THICKNESS (mm)				
		2.82				
1.850 x 1.400	0.6	5.0				
1.930 x 1.450	0.6	4.8				
2.130 x 1.550	0.6	4.4				
2.210 x 1.600	0.6	4.2				
2.340 x 1.650	0.6	4.0				
2.490 x 1.750	0.8	3.7				
2.690 x 1.850	0.8	3.5				
2.970 x 2.010	0.8	3.1				
3.250 x 2.110	0.8	2.9				
3.330 x 2.160	1.0	2.8				
3.610 x 2.310	1.0	2.1				
3.860 x 2.460	1.0	1.8				
3.910 x 2.540	1.3	1.8				
4.090 x 2.570	1.3	1.5				

SSPPA, 152 m x 51 mm CORRUGATIONS 787-mm CORNER RADIUS						
PIPE DIMENSIONS ② SPAN x RISE (m)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) ③				
		MINIMUM METAL THICKNESS (mm)				
		2.82	3.56	4.32	4.79	
4.110 x 2.900	0.8	3.9				
4.320 x 3.000	0.8	3.7				
4.750 x 3.200	0.8	3.4				
4.830 x 3.250	0.8		3.3			
5.230 x 3.450	0.8		3.1			
5.460 x 3.560	0.8			2.9		
5.510 x 3.610	0.8			2.9		
5.720 x 3.710	1.0			2.8		
6.070 x 3.910	1.0				2.6	
6.270 x 4.010	1.0				2.6	

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

For all SSPPA pipes, the top of the pipe should be located 0.3 m below the surfacing subgrade.

Notes:

① *These sizes should not be specified unless site conditions preclude the use of CSPA or SSPPA with 787 mm corner radii.*

② *Intermediate sizes not listed have the same maximum and minimum fill heights and metal thicknesses as the next larger size listed in this table.*

③ *Based upon a 192 kPa corner bearing pressure. Special foundation investigation required when higher corner bearing pressures need to be developed.*

STRUCTURAL REQUIREMENTS FOR SSPPA

Figure 17.1F

68 mm x 13 mm CORRUGATIONS①, ②, ③ LOCK-SEAM ALUMINUM PIPE						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) METAL THICKNESS (mm)				
		1.52	1.91	2.67	3.43	4.17
300	0.5	34.4	43.3			
450	0.5	22.9	28.7			
600	0.5	17.1	21.6	30.2		
750	0.5		17.1	24.1		
900	0.5		14.3	20.1	25.9	
1050	0.5			17.1	22.3	
1200	0.5			14.9	19.2	23.8
1350	0.5			13.1	17.1	21.0
1500	0.5				15.2	18.9
1650	0.5					17.1
1800	0.5					13.7

75 mm x 25 mm CORRUGATIONS ①, ②, ③ LOCK-SEAM ALUMINUM PIPE						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) METAL THICKNESS (mm)				
		1.52	1.91	2.67	3.43	4.17
750	0.5	15.8	19.8	27.7		
900	0.5	13.1	16.5	23.2	29.9	
1050	0.5	11.0	14.0	19.8	25.6	
1200	0.5	9.8	12.2	17.4	22.3	27.4
1350	0.5	8.5	10.7	15.2	19.8	24.4
1500	0.5		9.8	13.7	17.7	21.9
1650	0.5		8.5	12.5	16.2	19.8
1800	0.5		7.9	11.3	14.6	18.0

* *Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.*

For all aluminum pipes, the top of the pipe should be located 0.1 m below the surfacing subgrade.

Notes:

① *Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.*

② *For a given fill height, the wall thicknesses for both the 68 mm x 13 mm and the 75 mm x 25 mm corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.*

③ *Fill heights taken from manufacturers'/suppliers' product information.*

STRUCTURAL REQUIREMENTS FOR CAP (Lock-Seam Aluminum)

Figure 17.1G

17.1.9.1 Reinforced Concrete Pipe

Where fill slopes are 2:1 or steeper, concrete culverts less than 1500 mm in diameter will have no special end treatment and will extend 0.5 m beyond the toe of the fill slope. For pipes ≥ 1500 mm, RCP terminal sections will be specified.

Where fill slopes are flatter than 2:1, RCP terminal sections will be specified for all concrete pipe.

17.1.9.2 Corrugated Metal Pipe ≤ 1200 mm

Where fill slopes are 2:1 or steeper, metal culverts 1200 mm or less in diameter will have no special end treatment and will extend 0.5 m beyond the toe of the fill slope.

Where fill slopes are flatter than 2:1, the following end treatment sections will be specified:

1200 mm or less	CMP Flared End Terminal Section (FETS)
1340 mm S x 1050 mm R or less	CMP Arch FETS

17.1.9.3 Corrugated Metal Pipe and Structural Plate Pipe ≥ 1350 mm

The end treatments for the types and sizes of culverts listed below apply to all fill slopes:

1350 mm or greater	Step Bevel for CSP, SSPP and CAP
1520 mm S x 1170 mm R or greater	Bevel on CSP Arch
1.850 m S x 1.400 m R or greater	Bevel on SSPP Arch

Bevel defines the angle between the invert line and fill slope line.

17.1.9.4 Road Approach Culverts

Locate road approach culverts outside the clear zone where practical. FETS will be provided for all approach culverts located outside the clear zone. Where it is not practical to place approach culverts outside the clear zone, specify the 6:1 Road Approach Culvert End Treatment (RACET).

17.1.10 Roadway Orientation

The end treatments for all single concrete pipe and corrugated metal pipe installations with diameters less than 1350 mm will be installed perpendicular to the centerline of the pipe regardless of pipe skew, unless specified otherwise by the Hydraulics Section.

The following will apply to corrugated metal and structural plate pipe installations 1350 mm or greater in diameter:

1. Installations Perpendicular to the Roadway Centerline. Pipes will typically be designed and fabricated with the beveled ends perpendicular to the centerline of the pipe. The type of bevel will be identified on the plans (e.g., 2:1 step-bevel, 2:1 bevel, etc.).

2. Skewed Installations. The skew is defined as the angle measured left or right from a line which is perpendicular to the roadway centerline. Note: Skew-bevel or skew step-bevel end sections are cut parallel to the centerline of the roadway. The type of bevel and the amount of skew are to be identified in the Culvert Summary:

    a. Pipe skews will typically not exceed 35°.

    b. The pipe end treatment for single pipe installations will be designed as indicated below for the following skews:

0 to 15°	End treatment perpendicular to the centerline of pipe.
16° to 35°	When the fill height is less than 3 m, the end treatment should be skew beveled.
16° to 35°	When the fill height is greater than 3 m, the end treatment should be perpendicular to the centerline of the pipe and the fill warped to the pipe ends.

    c. Multiple pipe installations will utilize the same end treatment as single pipe installations except that, for skews from 16° to 35°, the end treatment will be skew beveled regardless of fill height.

    d. If it is determined necessary to skew-bevel a pipe end, provide concrete edge protection and cutoff walls on both ends.

    e. If temporary bracing of skew-beveled pipe ends is required, it must be addressed by special provision.

f. Concrete pipes will not be beveled or skew-beveled.

g. Consider channel changes to limit pipe skew where appropriate. Environmental concerns need to be considered when using this policy.

17.1.11 Metal Pipe Culvert Extensions

The following will apply:

1. The Hydraulics Section will evaluate the remaining service life of the pipe to determine if it should be extended or replaced. This determination is generally based on the condition of the in-place culverts.

2. The length of extension includes the new end treatment section, unless the existing section will be removed and relayed. Note this in the culvert summary.

3. The road designer is responsible for determining the length of pipe extensions. The Hydraulics Section may recommend new end treatments.

4. The diameter of the existing pipe will be converted to metric units and rounded to the nearest millimeter (e.g., 24" = 610 mm). The pipe extensions will be called out using the available metric size for that pipe. When the material or configuration of the existing pipe cannot be matched, a concrete collar will be needed to connect the extension to the existing pipe. Metal bands can be used to connect CSP to SSPP where the connection is beyond the edge of the surfacing section. This will require a special detail.

17.1.12 RCP Culvert Extensions

The required minimum length of extension for concrete culverts is as follows:

1. Diameter ≤ 750 mm: 3 m, including 1.0 m of new pipe and a 2.0 m standard terminal section

2. 750 mm < Diameter ≤ 1800 mm: 3.5 m, including 1.0 m of new pipe and a 2.5 m standard terminal section

3. Diameter > 1800 mm: Contact the Hydraulics Section

4. If extension of the barrel is not required, FETS can be added without the additional length of pipe.

5. The call out for the diameter of the existing concrete pipe will be the actual diameter converted to metric units and rounded to the nearest millimeter. When true metric size concrete pipe becomes available, concrete collars will be necessary to attach it to existing pipe.

17.1.13 Culvert Bedding

Use the *MDT Detailed Drawings* and Figure 17.1H to specify culvert bedding.

For most ordinary culvert installations less than or equal to 1200 mm in diameter, it will not be necessary to include bedding quantities in the plans unless specifically recommended by the Hydraulics or Geotechnical Section.

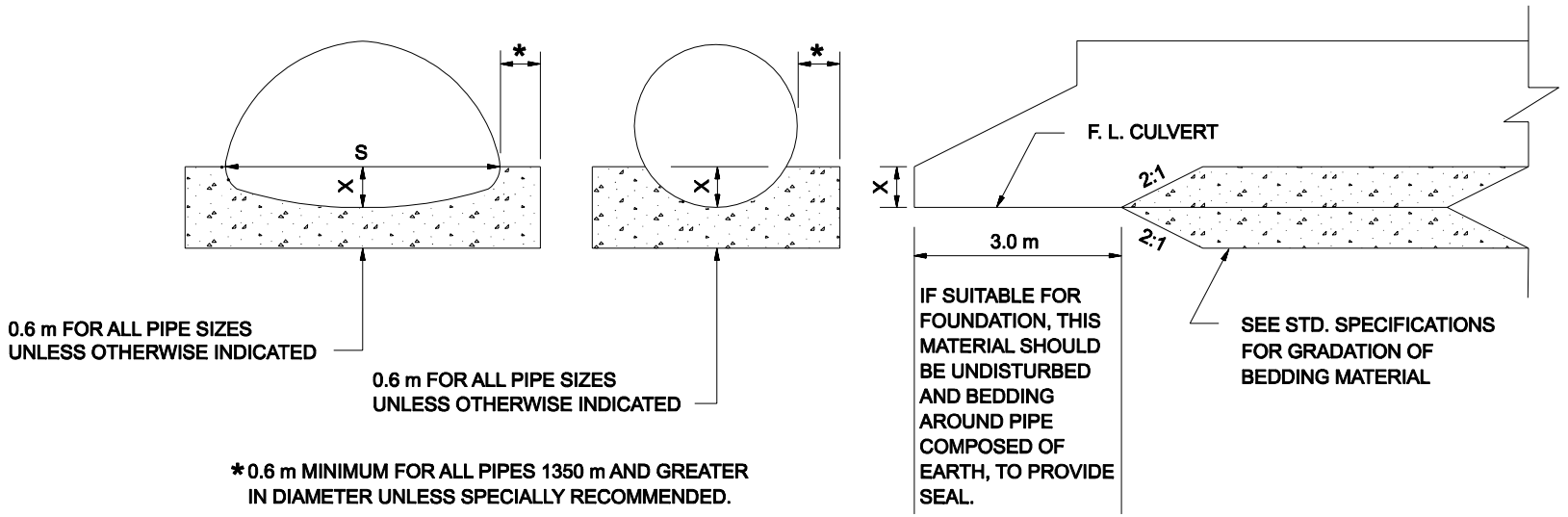
For all culvert installations of 1350 mm in diameter and larger (and equivalent size arch culverts — 1620 mm x 1100 mm for 68 mm x 13 mm corrugations and 1520 mm x 1170 m for 75 mm x 25 mm corrugations), specify bedding materials in accordance with the detail shown in Figure 17.1H. See the *MDT Detailed Drawings* for guidance when specifying culvert bedding quantities for a specific installation.

When foundation material is specified, it will be placed below the bedding material. Consult the Geotechnical Section for special foundation requirements when unusual subsurface conditions exist.

17.1.14 Culvert Inlet and Outlet Protection

The hydraulic characteristics of some drainage channels may require special protection for the roadway embankment at the inlets and outlets of culvert installations. Recommendations for special protection measures will be made at the time of the location survey or during subsequent field investigations. The Hydraulics Section will provide design information for special features.

If skew bevels are used, concrete edge protection is required to strengthen the top arch on the pipe inlet and outlet. Bolting should be similar to that shown in the MDT Detailed Drawings.



BEDDING MATERIALS
(Culverts with D ≥ 1350 mm)

Figure 17.1H

For pipes 1200 mm or less in diameter, it is not necessary to provide for special protection unless specific recommendations have been received to do so. For pipes of 1350 mm in diameter and larger, provide the protective measures described in the *MDT Detailed Drawings* for, as applicable:

1. Cutoff walls at both ends,
2. Concrete edge protection at inlet, and/or
3. Culvert riprap at outlet only.

Concrete pipe 1350 mm or larger in diameter that has standard end treatment should be provided with cutoff walls at both ends. However, concrete edge protection and culvert riprap should not be used in conjunction with the standard end treatment for concrete pipe unless specified by the Hydraulics Section.

See the *MDT Detailed Drawings* for estimated quantities for cutoff walls, edge protection and culvert riprap.

17.1.14.1 Riprap

The Hydraulics Section will typically design embankment protection, outlet aprons and other permanent erosion control features which require riprap. The road designer will calculate quantities and provide the necessary details. Show the riprap on the plans and cross sections and include the quantities in the appropriate summary.

The layout and quantities of riprap at bridge ends will be provided by the Bridge Bureau. It will be shown on both the plan and profile, and the quantities will be included in the appropriate summary.

With the exception of culvert riprap (i.e., edge protection), geotextile will be provided with all riprap installations unless otherwise specified.

17.2 SPECIAL DRAINAGE FACILITIES

17.2.1 Embankment Protectors

Generally, install embankment protectors, as shown in the *MDT Detail Drawings*, at the corners of bridges and on high fills to control runoff. Do not install embankment protectors for bridges having rail configurations without curb (e.g., T101 rail). Typical installations for bridges are described in the following:

1. Four-lane divided highway on tangent:

    a. Embankment protectors at the 4 outside corners.

    b. Bituminous curb at the 4 inside (median side) corners.

    c. Median drains with median inlet and cross drain or an outlet between structures with an embankment protector. Ditch blocks should be installed at the median inlet, and bituminous curbs should be designed to prevent drainage from running around the structure wingwalls.

2. Four-lane divided highway on curve:

    a. Embankment protectors on the 2 outside corners on low side of curve.

    b. Bituminous curb at the 2 inside (median side) corners on low side of curve.

    c. Median drains same as on tangent section.

3. Two-lane or four-lane with narrow median:

    a. On tangent — embankment protectors at 4 corners.

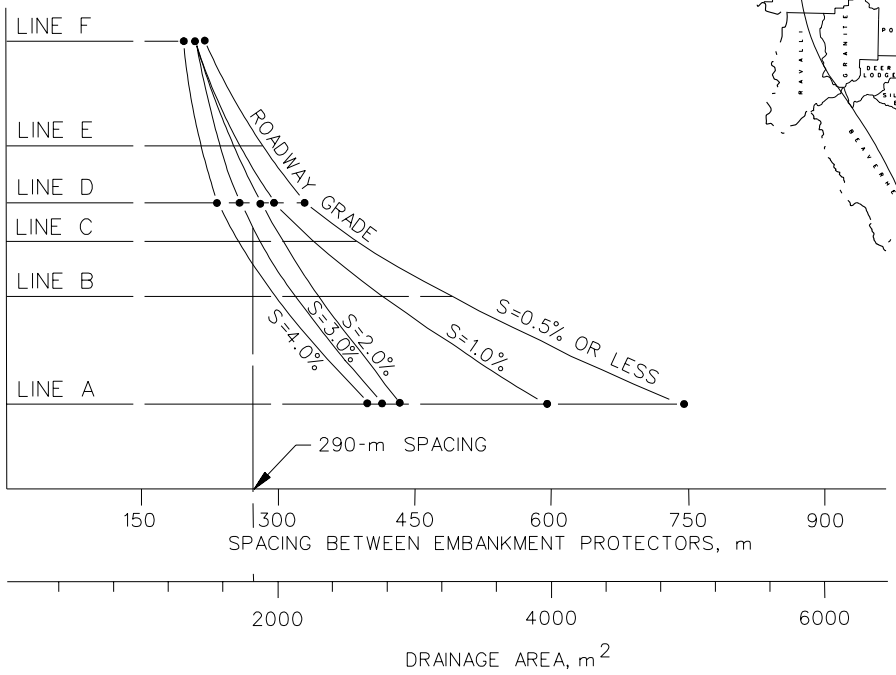
    b. On curve — embankment protectors at 2 corners on low side of curve.

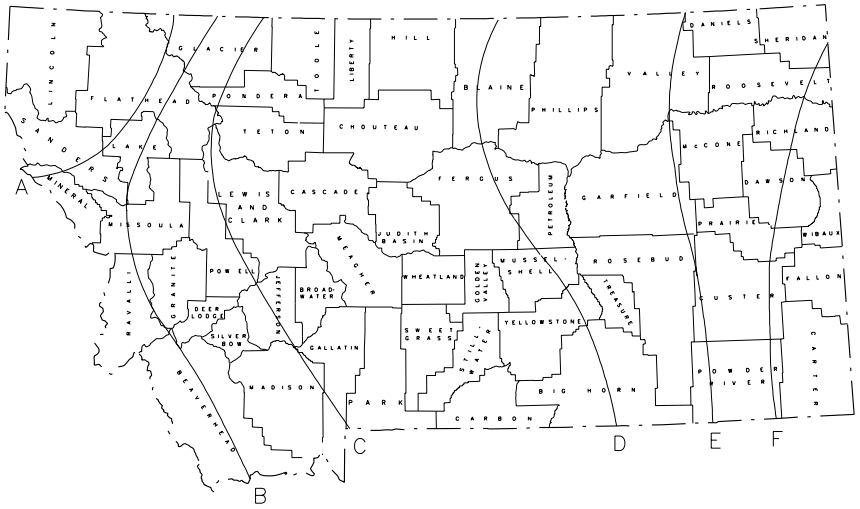
Where drainage flows toward the structure, place embankment protectors as near the structure as practical. On long, continuous sections of high fill, locate embankment protectors at intervals not exceeding the spacing shown on Figure 17.2A. Figure 17.2B prescribes appropriate spacings for median inlets. Embankment protectors must be used in conjunction with bituminous curb.

Example:

Location: Shelby
Road Grade: 3.0%

Shelby is located between C&D
From chart, spacing = 290 m
This spacing will also accommodate 1900 m2. Check the actual area. If it is greater than 1900 m2, the embankment protector spacing should be reduced.



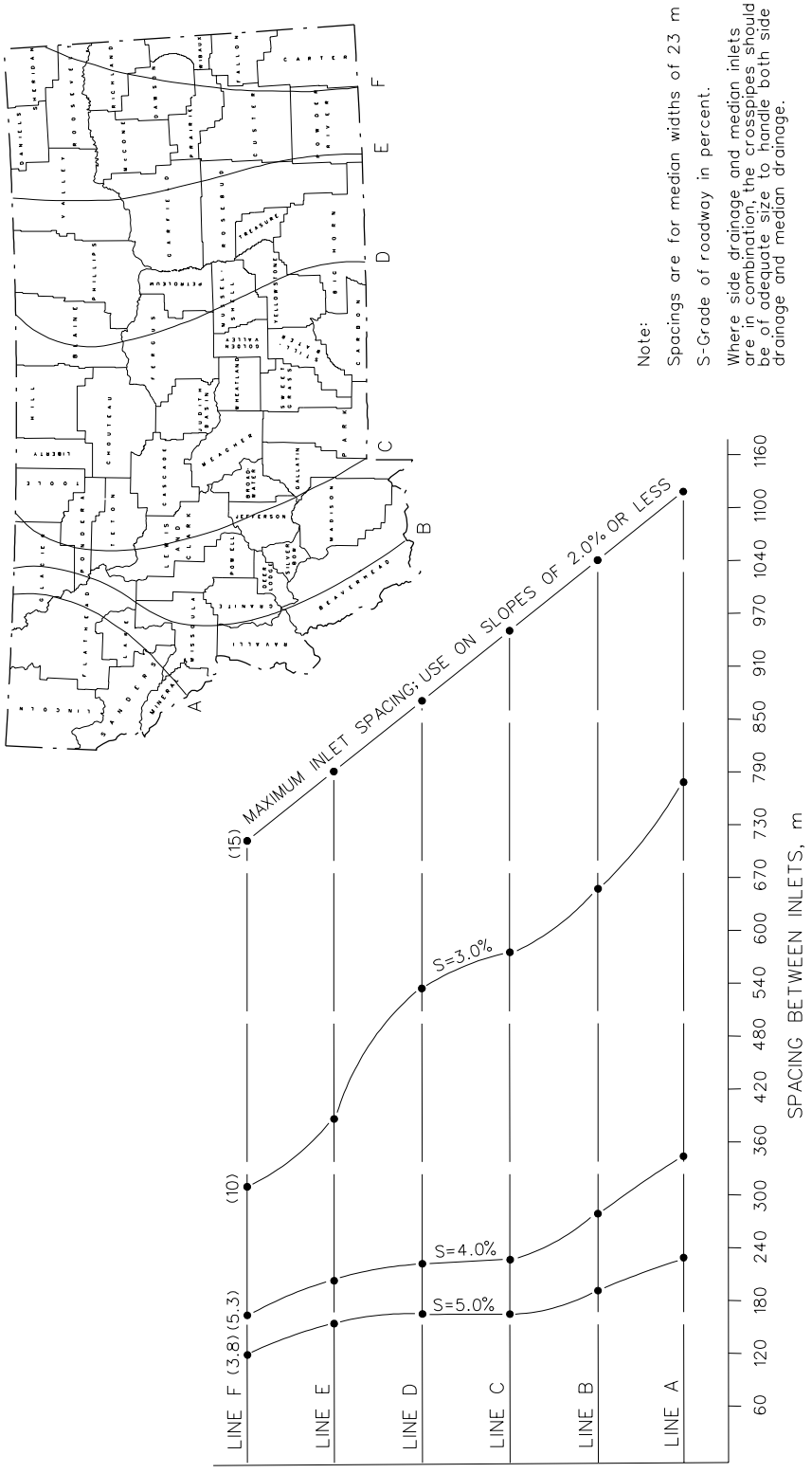


Note:

Bituminous curb must be in place for this spacing criteria to apply. Spacings are for ½ roadway width on tangent sections. Where protectors are needed on curve sections, compute area to be drained by protector, and check the area with the area scale. If the computed area is greater than the scale reading, reduce the spacing of the embankment protectors.

EMBANKMENT PROTECTOR SPACING

Figure 17.2A



MEDIAN INLET SPACING

Figure 17.2B

17.2.2 Drainage Chutes

The Concrete Drainage Chute described in the *MDT Detailed Drawings* may be used for backslope protection where the backslope intercepts a natural drainage coulee. Riprap and grouted riprap drainage chutes may be used in place of concrete.

17.2.3 Median Inlets

Three types of median inlets are available. Each type is shown in the *MDT Detailed Drawings.*

Specify the type clearly on the plans. Tables on the applicable *MDT Detailed Drawings* present estimated quantities of materials, but the bid item will be for the "Median Inlet Cover."

17.3 IRRIGATION FACILITIES

17.3.1 Irrigation Pipe

Irrigation facilities will require water-tight pipe. In the culvert summary and the culvert summary recap, record these pipes separately and identify them as "Irrigation" or "Siphon."

The Hydraulics Section will provide flowline and pipe invert elevations for irrigation installations. This is critical to effective operation. Minor irrigation pipes (450 mm) can be placed on the plans and cross sections by the designer without a recommendation from the Hydraulics Section. The Hydraulics Section will review these items for accuracy. If there are unusual conditions, coordinate with the Hydraulics Section to prepare clear, specific details on the plans.

Aluminum is not an option for irrigation pipe.

17.3.2 Irrigation Siphon Pipe

Some irrigation pipes will be "siphons," where the pipes are bent down under the roadway with the inlet and outlet elevations higher than the roadway centerline. Siphons will be designed and the Siphon Detail Sheet will be provided by the Hydraulics Section.

17.3.3 Division Boxes

Where existing irrigation ditches are disturbed, it may be necessary to provide new division boxes. The Hydraulics Section will provide the design and details for concrete division boxes. Some types of division boxes are shown in the *MDT Detailed Drawings*.

17.3.4 Irrigation Ditch Relocations

Relocate longitudinal irrigation ditches outside of the right-of-way line. The Hydraulics Section will provide recommendations for ditch linings, if required.

To avoid irrigation ditch maintenance within the highway right-of-way, irrigation culverts of 750 mm diameter and less should be extended 0.5 m beyond the R/W line where practical. The R/W fence may be winged into the pipe ends for irrigation pipes larger than 750 mm diameter to minimize the cost of pipe extension.

17.3.5 Inlet and Outlet Headwalls

The Hydraulics Section will provide recommendations and design details for concrete headwalls. Some headwall details are included in the *MDT Detailed Drawings*.

17.4 STORM DRAINS

The detailed design of underground storm drains will be prepared by the Hydraulics Section. The design will include the size, type and location of the trunk line, manholes and drop inlets. The Hydraulics Section will also provide trench and bedding typical sections for the trunk line.

The road designer will be responsible for calculating the quantity of culvert or trench excavation, bedding and length of lateral lines. Record all quantities for the storm drain facility in the appropriate frames. In addition, check the finished grade elevations at manholes and drop inlets and ensure that adequate cover is provided for the trunk line and laterals.

17.4.1 Storm Drain Inlets

The Hydraulics Section will recommend the types and locations. Details for the storm drain inlets are provided in the *MDT Detailed Drawings*.

The road designer should check the inlet locations to determine if they are located at low points of sags. Also check the inlet locations to determine if conflicts exist with curb ramps, in-place utilities, approaches or other features.

17.4.2 Manholes

The size and location of manholes will be specified by the Hydraulics Section. The road designer should check the locations to determine if conflicts exist. Existing manholes can be adjusted up a maximum of 0.3 m through the use of adjusting rings to match new grades.

Manholes which have been previously adjusted and manholes that require adjustments greater than 0.3 m will require additional investigation and may result in substantial modification or replacement of the existing manhole.

17.5 UNDERDRAINS

Unusual subsurface water conditions frequently are encountered during field locations and soils surveys. Some form of underdrain will be recommended by the Geotechnical Section to alleviate such conditions.

For each underdrain, the details should clearly define the location, the type, the depth of placement and the drain aggregate and geotextile to be installed with the pipe.

17.6 SPECIAL-PURPOSE LARGE CULVERTS

Large culverts frequently may be used for purposes other than to accommodate drainage. They may serve as stockpasses or vehicular underpasses with surfacing. The designer will be advised by the Right-of-Way Bureau when conditions warrant these installations. The following criteria present guidance for special-purpose large culverts.

17.6.1 Stockpasses

A standard metal pipe may be designed to serve as a stockpass by using the treatment shown in the *MDT Detailed Drawings*. It should be specified only when justified by right-of-way negotiations. The primary purpose of this structure is to serve as a stockpass. However, the majority of stockpasses also act as cross drains. Where drainage is not a consideration, the design elevation should be so as to avoid water flow. Adjacent, lower elevation culverts may also be provided for drainage when necessary.

The length is measured along the invert of the pipe. A right-angle crossing is preferred; however, if a skew is necessary, it should not exceed 15°.

Record stockpass culverts in a separate summary frame. Include associated paving in the additional surfacing frame.

Bedding material is required under the structure as required for CSP drain culverts of equivalent size. See Figure 17.1G.

Adhere to the maximum and minimum fill height requirements in the fill height tables.

17.6.2 Vehicular Underpasses

Specify the circular SSPPC vehicular underpass unless directed otherwise by the Hydraulics or Geotechnical Sections. Construction and design personnel should review the installation for special construction requirements when stage construction may be specified.

Record the quantities for vehicular underpasses in a separate summary frame.

Bedding material should be specified for all large culverts.

The *MDT Detailed Drawings* show requirements for a backfill retainer and cutoff wall and criteria for surfacing the floor of the underpass. The concrete collar shown in the *MDT Detailed Drawings* will be provided for vehicular underpasses.

Adhere to the maximum and minimum fill height requirements in the fill height tables.

17.7 CULVERT EXCAVATION MEASUREMENT

Estimate the quantities of required culvert excavation for all culvert installations as follows:.

1. Where bedding and/or foundation material is not specified, use the bottom of the pipe for the bottom limit of culvert excavation.

2. Where bedding and/or foundation material is specified, note the additional depth and width necessary to accommodate the bedding and/or foundation material as culvert excavation.

3. It is assumed that roadway excavation will be completed before culvert excavation is performed. Therefore, in cut sections, use the top of the new subgrade template as the upper limit of culvert excavation.

4. In fill sections, use the original ground line as the upper limit of culvert excavation.

5. Excavation for division boxes, cutoff walls, drop inlets, manholes and other minor structures will not be measured separately, but will be considered incidental to and absorbed in the contract unit price bid for the respective structure.

17.7.1 Culvert Excavation

The quantity of culvert excavation to be measured for payment will be the volume bounded on the bottom by the elevations established for the excavation floor, on the sides by vertical planes 0.3 m outside the inside walls of the pipe or culvert and on the ends by vertical lines 0.3 m outside of the neat lines of the pipe or culvert, unless otherwise specified in the contract. Where bedding and/or foundation material is specified, measure the volume bounded by the bottom and vertical sides of the bedding and/or foundation material and on the ends by vertical planes 0.3 m beyond the ends of the pipe.

Culvert excavation will be paid as a separate bid item for all installations including the extension of existing pipes, for all culverts 1350 mm and larger.

Culvert excavation will be paid for as a separate bid item or included in the cost of length of new pipe for all pipes less than 1350 mm. The method of payment will depend on the work being performed at each specific crossing as described in the following sections.

17.7.1.1 Calculate Culvert Excavation (Culverts ≤ 1200 mm)

1. New pipe installation.
2. Replacement of existing pipe.
3. Removal of existing pipe.
4. Remove and relay existing end treatment.
5. New approach pipes installed at existing approaches.

17.7.1.2 Include Excavation in Cost of Length of New Pipe (Culverts ≤ 1200 mm)

1. Extend existing pipe.
2. New pipes installed at new approaches.

17.7.1.3 Trench Excavation

The quantity of trench excavation to be measured for payment will be the volume bounded on the bottom by the elevations established for the excavation floor, bounded on the sides by vertical planes 0.5 m outside the inside walls of the pipe or culvert and on the ends by vertical planes 0.3 m outside the neat lines of the pipe or culvert, unless otherwise specified in the contract. Where bedding and/or foundation material is specified, measure the volume bounded by the bottom and vertical sides of the bedding and/or foundation material and on the ends by vertical planes 0.3 m beyond the ends of the pipe.

Trench excavation is typically used on urban projects and consists of the excavation for placement or removal of storm drains, sanitary sewers, water lines and other installations as necessary. In urban areas, use the ground line in place as the upper limit of the trench excavation.